DEPARTMENT OF THE INTERIOR, CANADA

Hon. W. J. Roche, Minister; W. W. Cory, Deputy Minister.

FORESTRY BRANCH—BULLETIN No. 49.

R. H. Campbell, Director of Forestry.

B45

TREATED WOOD-BLOCK PAVING

W. G. MITCHELL, M. Sc.

Contribution from Forest Products Laboratories

J. S. Bates, Chem. E., Ph. D., Superintendent

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

DEPARTMENT OF THE INTERIOR, CANADA

Hon. W. J. Roche, Minister; W. W. Cory, Deputy Minister.

FORESTRY BRANCH—BULLETIN No. 49.

R. H. Campbell, Director of Forestry.

TREATED WOOD-BLOCK PAVING

W. G. MITCHELL, M. Sc.

Contribution from Forest Products Laboratories

J. S. Bates, Chem. E., Ph. D., Superintendent

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

71785—1

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
FORESTRY BRANCH,
OTTAWA, October 14, 1914.

SIR,—I beg to transmit herewith the manuscript of a bulletin prepared by Mr. W. G. Mitchell, a member of the staff of the Forest Products Laboratories of Canada, entitled "Treated Wood-block Paving," and to recommend its publication as Bulletin No. 49 of this branch.

The supply of material for street paving is one which is giving a great deal of thought to the municipal authorities in Canada as elsewhere. In America generally the tendency has been toward using stone or other mineral as street-paving material, but in many of the cities in Europe, and increasingly so in recent years in the United States, wood-block pavements have been coming more into favour. They are superior in many ways to the pavements made of mineral substances, and if they can be so treated and laid as to stand heavy traffic and climatic conditions in Canada they will undoubtedly be the best paving material that can be obtained. The laying of such pavements will also make a very profitable use of wood from the Canadian forests if it can be demonstrated, as it undoubtedly can, that a number of the Canadian species of trees are very well adapted for use in wood-paving.

The bulletin herewith submitted is a compilation of the information at present available from researches made in different countries in regard to the use of wood for paving, which it is thought will be useful to Canadian municipalities that are making inquiry in regard to the matter. It is hoped to make some definite researches and investigations in Canada in connection with the matter later on.

Respectfully submitted,

R. H. CAMPBELL,
Director of Forestry.

W. W. CORY, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

DIAGRAMS.

TREATED WOOD-BLOCK PAVING.

The Forest Products Laboratories, recently established as a division of the Forestry Branch of the Department of the Interior, have early directed attention to the more pressing problems in connection with the utilization of forest products in Canada. The field of this division will be the investigation of all industrial possibilities of timber products, more particularly in the way of practical laboratory investigation of physical and mechanical properties of timber, and methods of preparation and manufacture of products.

At the present time, when the general subject of conservation of natural resources is receiving well merited attention, the establishment of this division fills a pressing need. Perhaps in no other industrial field are larger opportunities offered for the application of modern scientific methods than in connection with the wood-products industries. In some branches, present practice has reached a high stage of development, but all of the wood-using industries offer many problems of increasing commercial importance still to be solved. Chief among these is that of the possibility of the utilization of the by-products of manufacture, which are at present wasted, by the creation of new fields of use.

In the adoption of their general policy the Forest Products Laboratories have held closely in view the economic significance of the work to be undertaken, and it is the desire of this division to stimulate the interest of the various branches of the timber-using industry, and to enlist their active support, where possible, in the execution of such parts of their undertakings as may require outside co-operation.

At the present time, when the constantly growing volume and complexity of street traffic in cities, and the rising standards of public hygiene are forcing the attention of municipal and highway engineers throughout the country to the importance of the selection of road-surfacing material, the subject of wood-block paving is of most timely interest. In recent years, a few of the larger Canadian cities have adopted wood-block paving to a limited extent, but cities of Eastern Canada have been rather conservative in their attitude toward this type of paving.

In Canada, Vancouver has the largest area of treated wood-block pavement in service. At the present time the total length of creosoted wood-block pavement in that city is approximately twenty-three miles. Some of the earlier paving construction in Vancouver was with blocks treated by immersion in "Carbolineum," but subsequent to 1909 all creosoted blocks have been treated by pressure impregnation. Here, as in the comparatively few other Canadian cities where it was adopted, the dipped wood-block pavement has given good service during ten to twelve years of use. Pressure impregnation has, however, superseded immersion treatment almost entirely for paving-block manufacture.

The experience of those cities of the United States, where wood-block paving has been most extensively adopted, has shown that for many kinds of service creosoted wood-blocks are entitled to a high place in the classification of road-surfacing materials. In 1905 the total area of such pavement in the United States was slightly less than 1,500,000 square yards, while in 1913 the city of Minneapolis alone had in use over 1,000,000 square yards, which indicates in a striking way the extent to which this type of pavement has grown in favour during the last decade.

The Forest Products Laboratories have under consideration an extended investigation of the possibilities of treated wood-blocks for road-paving, dealing with the relative merits of different native woods, details of seasoning and preservative treatment and methods of laying, having particular regard to the climatic and traffic conditions to be met in Canadian cities. It is the intention of this department to place under

close observation several stretches of wood-block paving which are subject to representative conditions of service, in the hope of obtaining more or less direct correlation between the data gathered from periodical inspections and the results of laboratory investigations.

Pending the completion of such parts of this undertaking as will justify the publication of further reports, and to meet the present call for authentic information on the subject, this bulletin is offered largely as a compilation of the information available to date, and a summary of the published work of other investigators, whose experience with wood paving and wood-preservative treatment in general entitle their conclusions to the most careful consideration.

These Laboratories are indebted to the Forest Products Laboratory, of the United States Forest Service, Madison, Wis., U.S.A., for frequent reference to the published reports of that Bureau, to the American Wood Preservers' Association for references to recent contributions to that Society, and to the highway departments of many cities of the United States and Canada for information volunteered from their experience in this field.

HISTORICAL.

Apparently the first use of wood blocks for road-making, according to authentic records, was in Russia several centuries ago. In England and the United States wood-block pavements were adopted in a small way about eighty years ago. The record of such paving was far from satisfactory; in all cases the blocks were untreated, and in earliest practice were merely sawn from the log and laid as closely as this form would permit. Such paving was quite widely used in the Western States and in some Canadian cities, more particularly before the adoption of brick and asphalt surfaces. The foundation in most cases was of untreated planks, which after a short service decayed, permitting unequal subsidence of the blocks. In the case of round blocks the traffic wear was concentrated at the edges, and the interstices were collecting places for water and street refuse. Under such conditions the pavement soon became unsanitary, and deterioration was very rapid. Later, rectangular blocks were adopted with some improvement, but absorption of water was a cause of trouble, and after appreciable wear and settling of the foundation, it was practically impossible to maintain the condition of the surface. In part these early difficulties may have arisen from the indiscriminate use of woods most easily available, but the rapid decay was largely due to absorption of water and the collection of organic refuse around the blocks. In America, during comparatively early practice, a great many varieties of native woods were used for paving service. In London, England, particularly, and to some extent in New York, Australian wood was introduced, but in general the cost of such pavement was prohibitive, and the results not satisfactory. The woods so imported were chiefly of two species of eucalyptus, and were of hard dense structure, and their durability was supposed to have been due to some extent to their content of certain antiseptic gums.

Although the successful practical introduction of preservative treatment for timber dates from quite early in the last century, apparently its first adoption in connection with wood paving-block manufacture was about forty years ago. A case is noted of the laying of creosoted-block pavement in Galveston in 1873. The wood used in this case was southern pine, and, while the pavement was not laid in accordance with what is now recognized as best practice, it gave excellent results, and lasted until its destruction in the flood of 1900.

While the history of the development of wood preservation is exceedingly interesting, the subject is rather too extensive to be adequately treated within the scope of this report.

Briefly, the processes of wood preservation which have survived the tests of practice are: (1) kyanizing, (2) burnettizing, (3) creosoting, and (4) treatment with crude petroleum. The former, so-called from the inventor, Kyan, was introduced in

England in 1832. The method as first employed was the immersion of timber in a solution of mercuric chloride, a subsequent modification of the process providing for more rapid impregnation under pressure. In 1838 Sir William Burnett published a method of preservative treatment based on the antiseptic properties of zinc chloride. Pressure impregnation was also later applied to this process. Creosote oil—the heavy oil of tar—first made its appearance as a wood preservative in 1837, and in 1838 was used by John Bethell by injecting under pressure. The use of petroleum oils is of comparatively recent adoption. However, in modern practice this latter treatment is not so widely used as creosoting and burnettizing. Mercuric chloride and zinc chloride are both in use at the present time as wood preservatives, but the latter, because of its somewhat lower cost based on the quantities necessary for effective treatment, has been more extensively adopted than the corrosive sublimate. More recently, sodium fluoride and other fluorine compounds have been adopted as wood-preservative agents to a considerable extent in Europe. The antiseptic properties of sodium fluoride are relatively high, and it is probable that further experience will indicate that under certain conditions it is well adapted for such use. However, because of the solubility of these preservative agents, timber so treated is only available for conditions of service where it will not be exposed to excessive moisture, since otherwise the salts would be partially leached out and the value of the treatment greatly reduced. Moreover it is essential that wood-blocks to be used for paving purposes shall be as nearly as possible impervious to water; otherwise serious troubles will develop due to swelling and buckling of the pavement. Obviously impregnation with a water solution is of no value as a waterproofing treatment. These limitations preclude the adoption of such methods for paving-block treatment.

Treatment with creosote oil or heavier tar-products is, therefore, practically the only method applicable for paving-block manufacture. During recent years very considerable progress has been made in all lines of the timber-preservation industry both in Europe and the United States. Improvements in method of treatment, perfection of mechanical equipment used, the careful study of such factors as selection and seasoning of woods, and design and methods of laying pavement have combined to bring the development of wood-paving practice to a point where its adoption may no longer be considered an experiment, and where its possibilities in modern city-street paving merit most careful study.

RELATIVE MERITS OF VARIOUS PAVEMENT SURFACES.

The essential requisites of modern city paving are durability, safety, low traction-resistance and ease of cleaning. Considerations somewhat less important economically require that pavement shall be such that the noise and vibration from heavy street traffic will not be excessive, and that such factors as the radiation of heat, reflection of light and emission of unpleasant odours will be minimized. On a basis of the foregoing requirements, modern treated wood-block pavement is regarded by many authorities as closely approaching the ideal. The following table, compiled by the Forest Service of the United States Department of Agriculture, is representative of the opinions of a number of highway engineers in several of the larger cities of the United States.[1]

[1] C. L. Hill,—"Wood Paving in the United States" United States Forest Service Cir. 141.

Pavement Qualities.	Percentage.	Granite.	Sandstone.	Asphalt (sheet).	Asphalt (block).	Brick.	Macadam.	Creosoted wood.
Cheapness (first cost).	14	4·0	4·0	6·5	6·5	7·0	14·0	4·5
Durability.	20	20·0	17.5	10·0	14·0	12·5	6·0	14·0
Ease of maintenance	10	9·5	10·0	7·5	8·0	8·5	4·5	9·5
Ease of cleaning	14	10·0	11·0	14·0	14·0	12·5	6·0	14·0
Low traction resistance	14	8·5	9·5	14·0	13·5	12·5	8·0	14·0
Freedom from slipperiness (average of conditions)	7	5·5	7·0	3·5	4·5	5·5	6·5	4·0
Favourableness to travel	4	2·5	3·5	4·0	3·5	3·0	3·0	3·5
Acceptability.	4	2·0	2·5	3·5	3·5	2·5	2·5	4·0
Sanitary quality	13	9·0	8·5	13·0	12·0	10·5	4·5	12·5
Total number of points	100	71·0	73·5	76·0	79·5	74·5	55·0	80·0
Average cost per square yard laid 1905		$3.26	$3.50	$2.36	$2.29	$2.06	$0.99	$3.10

It is claimed that this table, published several years ago, is not fairly representative of results which are now being obtained from wood pavements which have been laid in accordance with more recent practice. Improved methods of treatment and laying, and greater care in the selection of timber stock have combined to produce a higher standard of durability than the above comparison would indicate.

EXTENT OF ADOPTION IN EUROPE AND AMERICA.

In English cities wooden-block pavement is held very highly in favour at the present time, and in the United States it is being more widely adopted as methods of practice are being settled. The growth of the wood-preserving industry in Europe and America has been most remarkable during the past ten years. In 1900 there were fifteen plants employing the pressure method of treatment in the United States; in 1913 this number had grown to ninety, a large proportion of which had been established by railway companies for the treatment of ties and other timber. The majority of these plants use creosote oil as a preservative, while many employ both creosoting and burnettizing, or in some cases a combination treatment. Briefly, the object of creosote impregnation is to increase the life of timber by prevention of decay, and by preventing the absorption of water, the latter consideration applying particularly to the treatment of wood intended for such service as street paving.

Wood-block paving has been very widely adopted in London, England; and to some extent in practically all of the larger industrial and commercial centres of England. In 1912 the amount of creosoted wood-block pavement in London had reached a total of 121 mil [illegible] the greater part of which is in use in Westminster and in the residential borough[illegible] [illegible] was in London that Australian hardwoods were first used for paving. These [illegible] were laid untreated, and the results have not fulfilled expectations. In recent [illegible] creosoted softwoods have entirely supplanted these species. In general the results from creosoted-block pavment have been highly satisfactory. In the London districts in which this pavement has been used most widely a considerable proportion of the traffic is comparatively non-destructive in character, heavy iron-tired vehicles being relatively few. However, a number of the most heavily travelled thoroughfares have been laid with wood-block paving.

In Paris, the extent of wood paving in use in 1912 was approximately 300,000 square yards. Imported hardwoods were used in Paris to a considerable extent, but are not held so highly in favour as formerly. Berlin has not adopted wood-block paving to any great extent. Apparently asphalt is most popular as a paving material, and this type of road surface has been developed to a high degree of perfection.

In the United States the reported area of creosoted wood-block paving in 1911 in some of the representative cities was as follows: Minneapolis, 950,000 square yards; Chicago, 700,000 square yards; New York, 650,000 square yards; Indianapolis, 500,000 square yards, and Cincinnati, 375,000 square yards. Exact figures are not available of the increase since that time, but there apparently has been a continued growth in use.

COMPARISON OF AMERICAN AND EUROPEAN PRACTICE.

In Europe the methods of creosote treatment of paving blocks vary considerably. In England the pressure method of impregnation is used, and specifications require an absorption of from 10 pounds to 12 pounds per cubic foot. The wood which has been used most extensively in England for paving-block manufacture is the so-called "Scotch" pine (*Pinus silvestris*), known also as Baltic or Swedish pine. This is a

By permission of Mr. S. R. Church, Barrett Mfg. Co., New York.

Laying 5-inch creosoted deal blocks on concrete foundation, Gracechurch street, London. Method of laying blocks. Blocks in foreground are loosely laid as delivered from wagons, and being moved up into position by the pavers.

clean uniform wood, of moderately close texture. In France, heretofore, the method of treatment has been by simple immersion in open tanks, and the absorption has been correspondingly small—from 3 pounds to 4 pounds per cubic foot. The time of immersion in this treatment was twenty minutes in oil of a temperature of 80 degrees Centigrade. Comparatively recently the modern methods of pressure impregnation have been adopted in Paris, and an installation has been completed for this method of treatment. A mixture of coal tar, pitch and creosote oil will be used in this case. The woods largely in use in France for paving purposes are Baltic pine and a native pine (*Pinus pinaster;* Eng., Cluster pine; Fr., Pin maritime), the latter of more open and less uniform structure than the former. In the United States pressure impregnation is used almost entirely for the treatment of paving blocks. A much heavier absorption is required by American specifications, up to 20 pounds or 22 pounds per cubic foot, although from 16 pounds to 20 pounds is the usual standard. At the present time

Laying 5-inch creosoted deal blocks on concrete foundation, Gracechurch street, London. Applying flush coat of pitch to the surface. In the background the pitch coat has been followed with a flush coat of cement grout.

Photos by permission of Mr. S. R. Church, Barrett Mfg Co. New York.

Laying 5-inch creosoted deal blocks on concrete foundation, Gracechurch street, London. General view of the work.

attention is turning to the possibility of adopting a lighter treatment for American woods. In American wood paving-block manufacture, those species which have been used include Southern pine, loblolly pine, Norway pine, Douglas fir, tamarack, white birch, larch, and hemlock. The experience with the latter two has not been satisfactory, and these species are not regarded as suitable for such service.

As factors contributing to the success of wood-block pavement, the methods of laying, cushioning and filling, and the workmanship of actual construction are details scarcely less important than the manufacture and treatment of the blocks. Regarding some points there is still considerable difference of opinion among highway engineers whose experience has been most extensive. In England the practice is to use blocks of somewhat greater depth than in America. Four inches is the minimum, and on heavily travelled thoroughfares 5-inch blocks are used. The b[illegible]s are in all cases laid with the grain vertical, and in European practice are of [illegible]y uniform section of 3-inch by 6-inch or 7-inch. In block-pavement constructio[illegible] England and on the Continent, the use of a sand cushion has been abandoned. The concrete foundation is laid and finished to an absolutely true contour of the finished pavement, either with or without the addition of a top mortar course, and this is allowed to set before the blocks are laid.

PAVEMENT CONSTRUCTION IN EUROPE: METHOD OF LAYING BLOCKS ON CONCRETE BASE.

England.—Here the custom is to lay the blocks in courses at 90 degrees to the street line, and with staggered joints. They are placed directly on the smooth concrete surface, and, after laying, a heated coal-tar-pitch filler is applied, and squeegeed into the joints. This is flushed with a comparatively thin Portland-cement mortar wash, and later a surface dressing of clean coarse sand is applied, and left to be worn in by traffic. This method of construction requires, of course, that the blocks be sawn to an absolutely uniform depth. Longitudinal expansion joints of 1-inch to 1½-inch width are provided along either curb, and are filled with the bituminous filler.

France.—Methods of pavement construction in France closely resemble those adopted in England. No cushioning medium is used, and in addition to the usual longitudinal expansion joints, transverse joints are provided at intervals of 100 feet or more. All such joints are filled with heavy paper box fillers, or in some cases with collapsible metal joints. Cement grout is generally used as a joint-filling material, although apparently pitch is adopted in some cases.

In *America* there is at present an even greater variety in methods of construction. Until comparatively recently sand cushioning has been in favour for all types of brick or block pavement. Such a cushion varies from one-half inch to 1½ inches or more in depth, according to the regularity of the surface of the foundation. This has been a frequent source of trouble. Particularly on grades and on heavily crowned streets the sand flows with the water which finds its way below the block surface, and this results in unequal settling of the blocks. This tendency to shifting of the cushioning material is apparently greater where the pavement is subjected to excessive vibration, as between car tracks. This defect is now being generally recognized, and leading authorities in pavement construction in the United States and Canada advocate a modification of European practice. They prefer a cement mortar bed of from one-half inch to 1 inch in depth, of 3:1 sand and Portland cement mixture, laid dry and struck off to a uniform depth with a template. The blocks are laid on this, and the pavement is sprinkled before and after laying and rolling the blocks. Sand filling for body joints has also been largely used, but is being displaced by bituminous material which should be selected of such composition that it will not run or become brittle at the extremes of temperature to which the pavement is exposed. American practice closely agrees with methods in vogue in England as to expansion joints and sand surfacing. It is claimed by some authorities that a more liberal allowance is necessary for expansion in American pavements. Whether this difference is due to climatic conditions, or to the difference in the woods used and methods of treatment is not entirely clear. A feature of

Laying 5-inch creosoted deal blocks on concrete foundation, Gracechurch street, London. Squeegeeing the pitch flush coat.

Photos by permission of Mr. S. R. Church, Barrett Mfg. Co., New York.
Laying 5-inch deep Swedish pine wood block in Paris. Cours la Reine—illustrating the expansion joint.

construction that has been introduced into the United States, apparently with successful results, is the laying of the block courses at an angle to the street line something less than 90 degrees. Inclinations of 45 degrees and 67½ degrees have been adopted, the latter apparently having given the best results. This practice was first introduced as a possible means of more evenly distributing the joint-wear from traffic, and to provide a longitudinal component of expansion movements.

Photo by permission of Mr. S. R. Church, Barrett Mfg. Co., New York.

Laying 5-inch deep Swedish pine wood block in Paris. Cours la Reine—Applying cement-sand grout to the surface of the pavement.

It is generally admitted that the success of European wood-block paving has been largely due to the high standard of workmanship secured. American operators now require more uniform methods and more careful work in actual construction than were formerly thought necessary.

By permission of Canadian Wood Preserving Co., Winnipeg.

Construction of Creosoted Wood Pavement on Scarth St., Regina, Saskatchewan. Progress Stages: Blocks being laid. Filler Squeegeed. Concrete Base finished. Sand Cushion being spread.

By permission of Republic Creosoting Co., Indianapolis.

Creosoted Wood-Block Pavement Construction, Minneapolis, Minn.

DEFECTS OF EARLY WOOD-BLOCK PAVEMENTS.

In earlier wood-block paving practice, faulty methods of treating and failure to appreciate the importance of such factors as the selection of proper timber-stock and careful workmanship in construction were responsible for unsatisfactory results which have developed a prejudice which has been slow to disappear. Insufficient impregnation was an error in French practice which has persisted until quite recently. The absorption of 3 pounds or 4 pounds per cubic foot, secured by simple immersion, proved quite inadequate to prevent decay, and the blocks so treated had a comparatively short life. In England, practice has become well settled in the adoption of a 10-pound or 12-pound impregnation. In America a much heavier treatment is generally favoured, and this is held by some authorities to be at least partially responsible for another difficulty which appears to have been peculiar to American pavements. "Bleeding" or exudation of the oil from treated blocks has been a rather frequent source of trouble in the United States. This condition, where it appears, develops in hot weather during the first season of use, and is probably due in large part to excessive treatment with an oil that is not adapted to such conditions of service. The character of the wood is probably to some extent a factor in causing this condition, inasmuch as heavier treatment is permissible, or even necessary, for some species. It has been claimed by some investigators that bleeding is largely due to the stresses developed in the pavement sheet as a result of the absorption of even comparatively small amounts of water. It is doubtful if this idea is confirmed by actual observation. A case has been noted of a pavement laid on a Chicago street, where the blocks used on the north side and south side of the street were obtained from different manufacturers. "Bleeding" developed on one side only (the north side) and apparently, all other conditions being uniform, the cause lay in the character of the oil used.

However, the responsibility for this trouble has not been finally distributed to the several factors which have been suggested as causes, and the matter is now under investigation in the United States.

Heaving and buckling of the pavement sheet have been frequent causes of trouble where insufficiently treated blocks have been used, and where adequate provision for expansion has not been made. Apparently not much difficulty is experienced from this cause in English practice, and it is probable that climatic conditions are in part responsible for the freedom from expansion troubles. It has been suggested that because of the comparatively high humidity, the blocks are in a condition of maximum expansion during the greater part of the time, and are not subject to the extremes to be met in the United States or Canada.

A criticism which has been directed against wood-block paving from some quarters is that it presents a dangerously slippery surface, when newly laid or when wet. However, this difficulty has been overcome in part by the adoption of a clean hard sand surface-dressing, as a final step in construction or at such later intervals as may be necessary. The sand is worked into the blocks by traffic, and serves the manifold purpose of developing a hard, resistant and non-slippery wearing surface, and reducing the nuisance from exudation of oil, where that occurs.

The difficulties due to insufficient impregnation are fairly clearly recognized. American practice is perhaps inclined to err on the other extreme, and, comparatively recently, attention has turned to the possibilities of certain processes which are claimed to secure maximum waterproofing and antiseptic effects with the use of less creosote oil than has heretofore been regarded as necessary.

Expansion troubles have been largely overcome by the provision of ample longitudinal joints. The American practice of laying the block courses at an angle of from 60 degrees to 70 degrees to the street line is claimed to reduce the tendency to buckling, in addition to reducing the wear along the joint lines.

The difficulties from the use of sand cushioning have already been referred to, and it is significant in this connection that there is now in the United States and Canada almost unanimous agreement upon a cement sand mortar cushion, or a very thin sand cushion, if on level streets.

By permission of Canadian Wood Preserving Co., Winnipeg

Wood-Block Pavement, Eighth Avenue, Calgary.

SPECIAL USES OF WOOD-BLOCK PAVING.

Wood-block paving has been adopted quite generally in America for such special service as bridge floors, and for flooring warehouses and industrial plants.

For bridge flooring it would seem to offer particular advantages, which will commend it to engineers. The practice is to lay the blocks on a base of treated planking varying in thickness from 3 inches to 5 inches, which is carried directly on the steel floor members. The reduction of dead loading accomplished by the adoption of such construction offers considerable opportunity for economy in design.

Brick or asphalt surfaces for highway bridge floors require a heavy concrete base, which adds greatly to the weight of the structure. The experience of a number of cities of the United States and Canada indicates that wood-block paving has amply and conclusively demonstrated its advantages for such use.

For flooring warehouses, loading platforms, and many types of industrial plants, wood paving would seem to be well suited. The peculiar requirements of such service make the choice of a flooring material of considerable importance. Trucking and handling of heavy materials result in rapid deterioration of non-resilient floors, and it is claimed that wood-block floors have given records of remarkable durability in this class of service.

In general the construction of such flooring is in accordance with the methods used in street paving. A concrete base is prepared and the blocks are laid with or without cushioning. Since for such use there is comparatively little exposure to water under ordinary circumstances, there is apparently not the same objection to sand cushioning as in street work, although vibration and impact of heavy loads may develop uneven settling on such a cushion layer. In bridge-floor construction and in building block floors laid on plank base, it is usual to provide a single layer of heavy pitch felt as a cushioning medium. This may or may not be swept with pitch filler before laying blocks.

EXPERIMENTAL PAVEMENT IN MINNEAPOLIS.

In order to obtain a representative and reliable record of results from actual service, an experimental pavement was laid in the city of Minneapolis in 1906, under the direction of the Forest Service of the United States Department of Agriculture.

The pavement was laid on Nicollet avenue, a practically level street, with a roadwidth of 50 feet. It was proposed to determine as far as possible the service record of the different wood species in common use for paving purposes, and also to estimate the importance of such factors as length of block, proportion of heart- and sap-wood, and angle of courses. The foundation was of concrete, a 1:3:7 mixture, 5 inches in thickness. This pavement was designed with a crown of 8 inches, and the blocks were placed on a 1-inch sand cushion, struck off to a uniform depth. A section of the finished pavement is shown in fig. 1.

The woods chosen for this pavement were longleaf pine, Douglas fir, western larch, Norway pine, tamarack, white birch, and hemlock. Of these the longleaf pine, Douglas fir, and larch were approximately all of heartwood, the Norway pine and tamarack were of mixed heart- and sapwood, while in the case of birch and hemlock the proportions were undeterminable. The blocks of longleaf pine, Norway pine, tamarack and Douglas fir varied from 6 to 10 inches in length. Hemlock blocks were 6 inches, one-half of the western larch and birch blocks were 6 inches and 8 inches, and one-half were of 4-inch length.

The depth of the blocks as laid, was approximately 4 inches—$3\frac{13}{16}$ inches for the white birch and larch, and $3\frac{15}{16}$ for the other species. The blocks were 4 inches wide in all cases.

By permission of Canadian Wood Preserving Co., Winnipeg.

C. P. R. High Level Bridge, Edmonton. Highway floor paved with creosoted wood blocks.

The blocks were treated with a creosote oil conforming to the following specifications:—

"The specific gravity of the oil at 20° C. shall be at least 1·09. The oil shall be completely liquid at 25° C., and shall show no deposit on cooling to 22° C. It shall not contain more than 2 per cent of water, nor more than 3 per cent of matter insoluble in absolute alcohol or benzine.

"Distillation test.—One hundred grams of oil shall be placed in an 8-ounce retort, fitted with a thermometer, the bottom of whose bulb shall be placed one-half inch above the oil, and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer, and the retort shall be covered in order to prevent too rapid radiation. The percentages are for dry oil, and by weight:—

"Up to 150° C., nothing must come off.
" 170° C., 2 per cent.
" 210° C., from 6 per cent to 8 per cent.
" 235° C., from 20 per cent to 30 per cent.
" 315° C., from 40 per cent to 50 per cent.
" 355° C., from 60 per cent to 80 per cent.

"Distillation shall be gradual and be completed up to 315° C., in 30 minutes from the first drop, and entirely completed in 40 minutes."*

The impregnation required was 16 pounds per cubic foot, but in the case of white birch and larch, this was increased to 20 pounds per cubic foot, to compensate as far as possible for the use of an oil which was somewhat lighter than the standard specified.

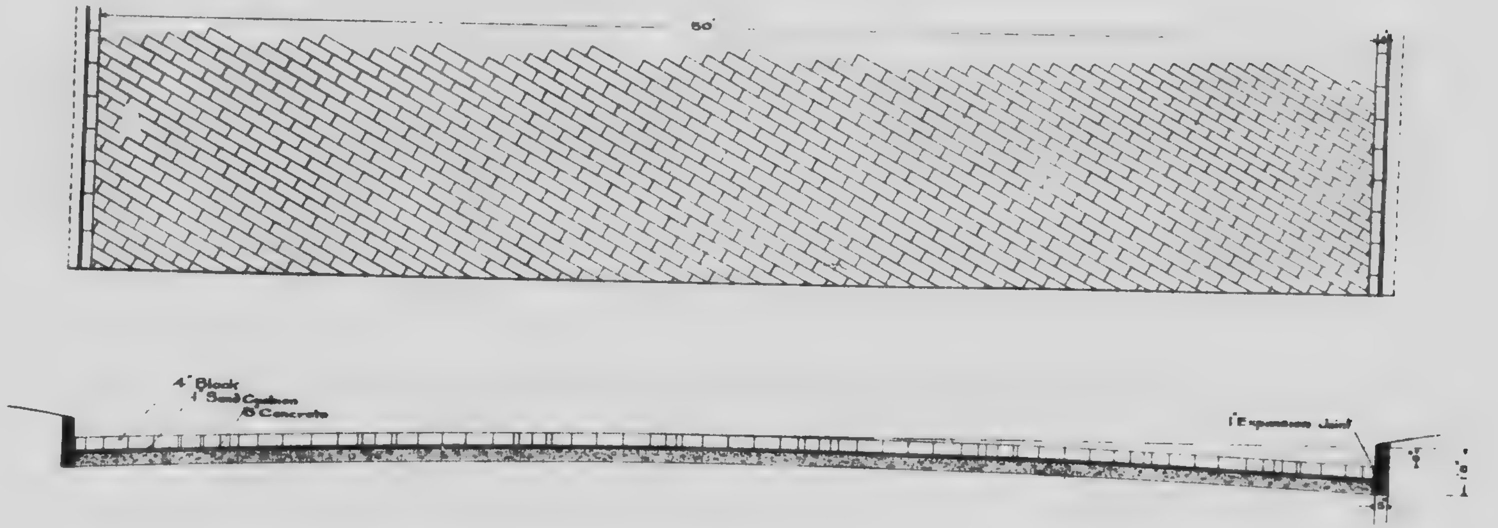
In the construction of the pavement, different stretches were laid with their courses respectively at 90 degrees, 67½ degrees, and 45 degrees to the curb. The blocks were laid with close joints, on a sand cushion, and rolled with a steam roller. A longitudinal expansion joint at each curb was filled with sand after thorough rolling of the block surface. The block joints and the top of expansion joints were then filled with pitch heated to 300° F., and brushed in. A sand dressing was then applied and left to be worn in by traffic.

It was proposed to make periodical inspections of the pavement to note results of service, and, in accordance with this idea, three systematic inspections have been made in 1910, 1912, and 1913, respectively. The method of determining wear at the time of inspection, was to select one block near the curb, and another which, from its position, half-way between the curb and the centre of the street, might be assumed to have been exposed to maximum traffic wear. The difference in the depths of the blocks was taken as a measure of the traffic abrasion. The proportion of areas of considerable depression below the general level of the street surface was estimated by different observers, and an average estimate taken. The result of the first of such inspections made in 1910 is briefly indicated in the table below:—*

*F. M. Bond: "Progress Report on Wood-paving Experiments in Minneapolis." U. S. Forest Servi e Cir. No. 194.

C. H. Teesdale: "Experiments with Wood-paving Blocks, City of Minneapolis, Minnesota." U. S. Forest Service, Forest Products Laboratory, Madison.

*F. M. Bond, "Progress Report on Wood-paving Experiments in Minneapolis." U.S. Fores Service, Circular No. 194.



(F. M. BOND. "PROGRESS REPORT ON WOOD-PAVING EXPERIMENTS IN MINNEAPOLIS")

PLAN AND SECTION OF EXPERIMENTAL PAVEMENT. MINNEAPOLIS.

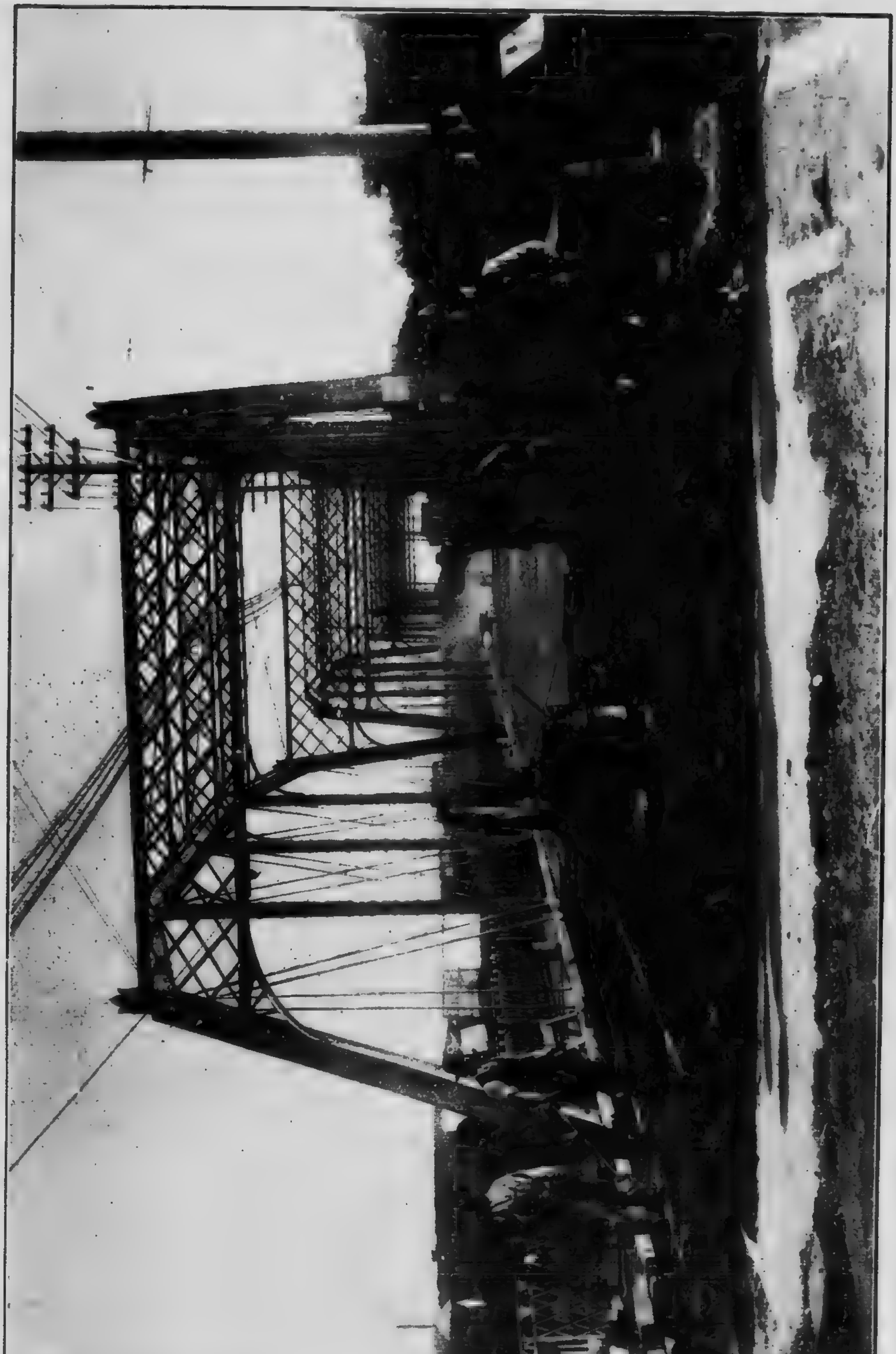
Species.	Area of section.	Original depth of block.	Depth of block of average wear for section.	Average wear of section.	Area local depression one-half inch and less below general level of section.	Area local depression one-half inch and less below general level of section.	Area local depression three inches to one-half inch below general level of section.	Remarks.
	sq. ft.	In	In.	In.	sq. ft.	p.c.	p.c.	
1. Norway Pine........	440	$3\frac{15}{16}$	$3\frac{3}{4}$	$\frac{3}{16}$	10	2·0	.....	All apparent depressions in one spot, possibly due to fire.
2. Tamarack	742	$3\frac{15}{16}$	$3\frac{3}{4}$	$\frac{3}{16}$	10	1·0	....	
3. White Birch (6-and 8-inch blocks)	1,609	$3\frac{13}{16}$	$3\frac{5}{8}$	$\frac{3}{16}$	8	0·5	....	About 40 to 50 blocks removed on account of decayed heart.
4. White Birch (4-inch blocks)	1,615	$3\frac{13}{16}$	$3\frac{5}{8}$	$\frac{3}{16}$	10	0·5	.....	Some blocks show. l decayed heart.
5. Western Larch (4-inch blocks)...........	1,505	$3\frac{13}{16}$	$3\frac{1}{2}$	$\frac{5}{16}$	33	2·0	.....	
6. Western Larch (6-and 8-inch blocks).....	1,497	$3\frac{13}{16}$	$3\frac{7}{16}$	$\frac{3}{8}$	55	3·5	.....	
7. Douglas Fir...... ...	1,229	$3\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{1}{16}$	......	30·0	35·0	Medium grain, 6 to 7 rings per inch.
8. "	1,293	$3\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{1}{16}$	......	30·0	3·0	Coarse grain, 3 to 5 rings per inch.
9. Longleaf Pine..	3,583	$3\frac{15}{16}$	$3\frac{7}{8}$	$\frac{1}{4}$	17	0·5	......	
10. Eastern Hemlock....	3,038	$3\frac{15}{16}$	$3\frac{3}{4}$	$\frac{3}{16}$	35	1·0	......	

The Douglas fir sections were in very bad condition after four years of service, and were replaced during the year 1911. This unsatisfactory result was thought to have been due to the use of a poor grade of timber, of rapid growth. Vertical shearing along the annual rings had so reduced the lateral support of the blocks that they were badly broomed, and in some cases worn to small pieces. This part of the pavement was relaid with first-grade Douglas fir blocks and hard Southern or yellow pine blocks. These blocks were treated in accordance with the best recognized methods at that time, and laid as before on a 1-inch cushion of clean sand.

Detailed traffic records were taken during the years of use of the experimental pavement, and these indicated an average tonnage of the vehicular traffic ranging from 127 tons per foot of roadway in 1906, to 154 tons per foot in 1910. Estimating that 90 per cent of this traffic was concentrated on the middle 25 feet of pavement, the corresponding traffic distribution per foot ranged from 228 tons to 278 tons in the above years.

The results of a third inspection in September, 1913, have recently been made public. The method of inspection on this occasion was the same as previously employed and described above. The various sections of the pavement, in order of least wear as determined at that time, ranked as indicated below:—

1. Section 4, White Birch.
2. Section 3, White Birch.
3. Section 5, Western Larch.
   Section 9, Longleaf Pine.
4. Section 1. Norway Pine.
5. Section 2, Tamarack.
6. Section 10, Eastern Hemlock.
7. Section 6, Western Larch.



Main St. Bridge, Winnipeg—Paved with Creosoted Wood Paving Blocks.

By permission of Canadian Wood Preserving Co., Winnipeg.

By permission of Republic Creosoting Co., Indianapolis.

Construction of Creosoted wood-block pavement on highway bridge, Piqua, Ohio.

Judged according to the development of areas of considerable depression, the durability of the different sections is indicated below:—

1. {Section 9, Longleaf Pine.
   {Section 3, White Birch.
2. Section 4, White Birch.
3. Section 1, Norway Pine.
4. Section 10, Eastern Hemlock.
5. Section 2, Tamarack.
6. Section 5, Western Larch.
7. Section 6, Western Larch.

So far as the importance of the different angles of courses is concerned, the following observations are made: Those sections laid at 90 degrees to the street line showed appreciable joint wear, those laid at 45 degrees and 67½ degrees showed no apparent joint wear, while those sections laid at 67½ degrees to the street line showed least area of local depression.

A summary of the results of three inspections indicated that in the case of all blocks but longleaf pine and white birch, there had been considerable increase in the development of areas of depression during the sixth year of service. The rate of average wear during the same year showed a slight increase in all except the 4-inch blocks of larch and birch. Longleaf pine showed the least total area of depression, and white birch suffered the least average wear. Western larch gave least satisfactory general results, with the exception of those stretches of Douglas fir which had been replaced in 1911, and of which fairly comparable records were not available. The effects of varying proportions of heartwood and sapwood were not distinguishable at the time of the last inspection.

IMPORTANT FACTORS.

From a careful consideration of the results of both European and American experience it would appear that the success of wood-block paving is dependent upon the following factors:—

(1) Selection of timber stock, with regard to its adaptability to conditions of service.

(2) Methods of seasoning and impregnation.

(3) Quality of creosote oil.

(4) Size of blocks, design of base and pavement, methods of filling, cushioning, surfacing and general standard of workmanship.

SELECTION OF TIMBER.

Longleaf pine has been most widely used in the United States, and has given excellent results. It is certainly most highly in favour in the Eastern and Southern States at the present time. In Europe, as before noted, other species of pine are almost universally used for the manufacture of treated-wood blocks.

Other American woods which have been used with success for the manufacture of wood-paving blocks are tamarack, birch, hemlock, Douglas fir, maple, Norway pine and larch. Obviously a wood of fairly close structure is desirable, and a usual specification in the case of hard (Southern) pine sets a minimum of from six to eight annual rings per inch measured radially from the heart. To secure uniform wear of surface, only one species of wood should be used in one pavement stretch. The selection of a wood will depend upon its adaptability to the conditions of service, which will depend upon such factors as strength and density of structure. The ease of impregnation is another feature of considerable importance, and finally such economic factors as availability of supply and transportation costs must influence the choice of timber.

By permission of Dominion Tar and Chemical Co.

Treated Wood-block flooring, machine shop floor.

A usual specification for paving-block stock requires a certain proportion of heartwood, generally 80 per cent. The value of this limitation has been disputed by some authorities, and authentic records of service performance of pavements where the influence of this factor has been investigated apparently do not indicate any considerable difference in the durability of heartwood and sapwood in the case of any species. The rigid enforcement of such a specification would no doubt increase the cost of blocks considerably, and it is difficult to say with any certainty what limitation would be justified in this connection, having in view the increased cost of production. Some authorities claim that, while in untreated wood, sapwood yields more readily to decay, in well seasoned, properly impregnated timber there is no difference in the durability of heartwood and sapwood. The results of the inspections of the Minneapolis experimental pavement apparently confirm this opinion. Other investigations have indicated that in sound untreated timber there is no appreciable difference in the strength of heartwood and sapwood, although, as stated above, sapwood is frequently prohibited in untreated timber specifications, because of its greater liability to decay.

METHODS OF TREATMENT.

The elimination of the natural moisture content of timber is an essential preliminary to successful impregnation with preservative. The details of practice in this connection are not uniform, but the same general purpose is served by various methods.

Thorough air seasoning generally precedes pressure treatment, although it has been claimed, in the case of some species at least, that equally satisfactory absorption can be secured with green or partially air-seasoned stock, if proper steaming and vacuum treatment is given prior to impregnation. The actual application of pressure in the treating cylinders may or may not be preceded by preliminary vacuum up to 26 inches of mercury. Heating or steaming before exhaustion may be resorted to in the case of insufficient air seasoning before the timber comes to the treatment cylinders. Over-heating of timber is injurious but in the case of light timber stock such as paving-blocks, it is possible to secure desired results without exceeding safe temperatures or unduly prolonging this part of the treatment. It is of interest to note in this connection that the specifications of the Bureau of Highways, Borough of Manhattan, New York City, provide for variation in cylinder treatment according to the average unit weight of blocks. The timber stock in this case is Southern longleaf pine, and according to specifications should be air-seasoned to a maximum weight of 50 pounds per cubic foot. The specifications provide that blocks shall be graded into four classes according to unit weight, viz., 38 to 42 pounds, 42 to 44 pounds, 44 to 46 pounds, and 46 to 50 pounds per cubic foot. In general the heavy blocks are given a preliminary steaming at a considerably higher temperature and for a longer period than the lighter blocks. Similarly the vacuum treatment following steaming of heavy blocks is specified to be slightly higher and to be maintained for a much longer time than in the case of lighter stock. Just how far this discrimination in treatment results in greater uniformity of impregnation is uncertain, but apparently this method has been adopted after considerable experience in treating longleaf pine.

Oil pressure is generally specified not to exceed 200 pounds per square inch, and for some species a lower pressure is required with a correspondingly longer time to insure sufficient absorption. Final vacuum is adopted in some methods of treatment, as a means of reducing subsequent "bleeding" of the blocks. A steam bath as a last step in cylinder treatment is recommended for cleaning blocks where creosote-tar mixtures are used.

One criticism which has been directed against Douglas fir is the difficulty of securing satisfactory penetration of preservative in air-dried timber. There is considerable diversity of opinion as to the best methods of treating Douglas fir paving blocks. It is held by some authorities that air seasoning of two or three months gives

best results so far as uniformity of penetration is concerned, and an absorption of from 10 pounds to 12 pounds per cubic foot is claimed to produce the most durable block.

CREOSOTE OIL.

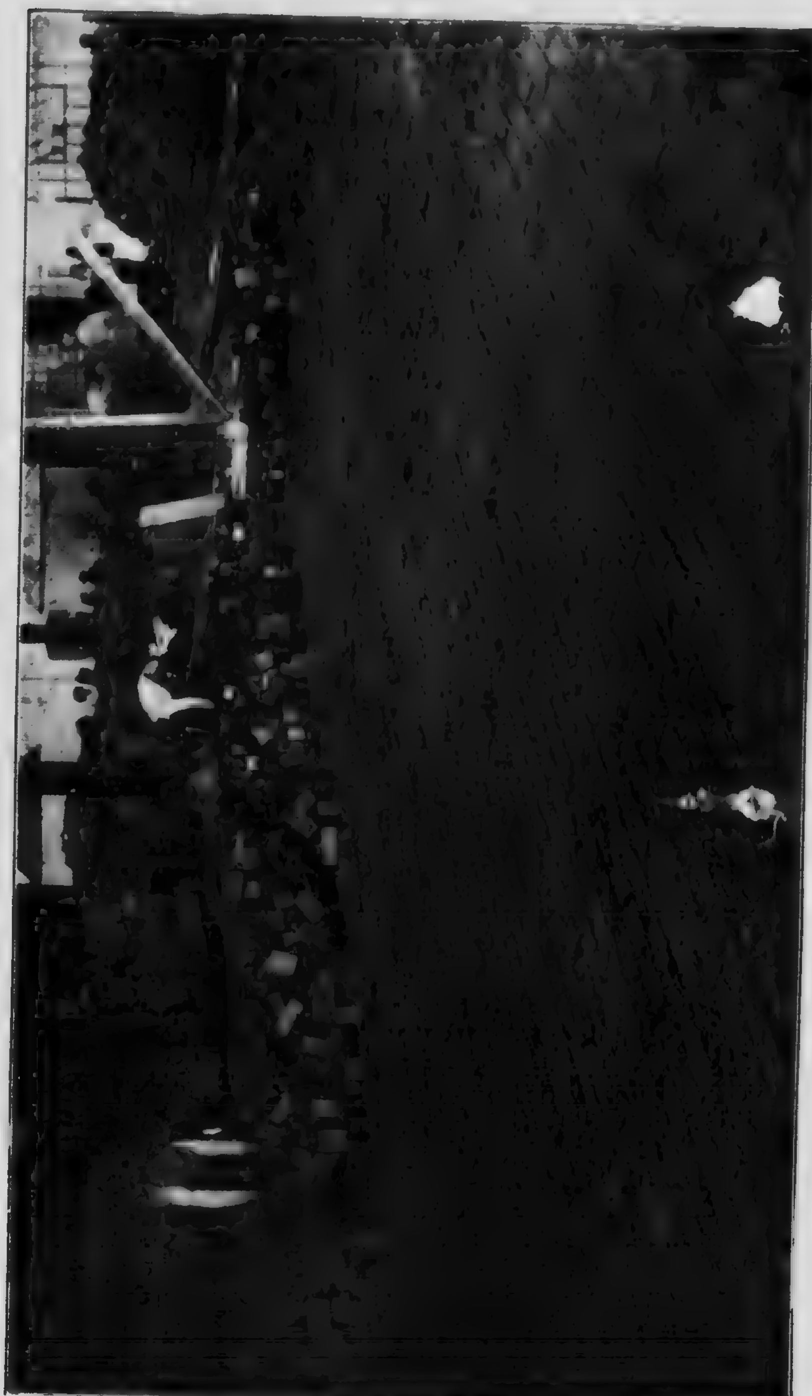
Creosote oil is a coal-tar distillate, and is obtained, commercially, from coal, water-gas or coke-oven tar. The requirements of creosote oil for wood preservation are manifold. It must be antiseptic, to prevent growth of wood-destroying organisms. It must be permanent, i.e., the loss by evaporation must be negligible. Finally, it should serve as a waterproof filler, a requisite that is of particular importance in the treatment of wood-paving blocks.

Since creosote is a mixture of a number of complex hydrocarbons of varying density and volatility, the specifications for oil for use as a wood preservative usually define its composition in part by the fractions distilled in various temperature intervals.

Since the loss by evaporation is higher in the low-boiling constituents, the necessity of using an oil sufficiently heavy to insure permanency is apparent. On the other hand the viscosity of the oil increases with the proportion of the tar content, and penetration is correspondingly more difficult. The usual specifications for wood-block creosote oil stipulate that the oil shall be free from raw tars. However, the addition of varying amounts of refined tar, even up to 20 per cent or 25 per cent, is a feature of some commercial methods of treatment. This practice has been subjected to some criticism, as it is claimed that the heavy tar constituents are filtered out by the comparatively dense structure of the winter-wood and appear only in the relatively porous spring-wood. It may be that the adulteration of reasonably heavy oils by the addition of tar within certain limits is justified. The purpose of such mixing is two-fold: (1) to obtain a heavy preservative and waterproofing medium, and (2) to reduce the cost of oil of equivalent density. Such tar must be low in free carbon content, and special methods of mixing are necessary to secure a uniform product. It is probable that impregnation with adulterated oils is more difficult than in the case of pure creosote, and treatment with such a mixture will require methods somewhat different to those necessary with straight oils.

The danger of such practice lies in the temptation to combine very light creosote oils with large amounts of tar, in an endeavour to obtain a final product of specified density. To what extent the addition of tar to creosote for certain uses in preservation is justified by the increasing cost of higher grades of oil is still an unsettled point. Some operators claim that the reduction in cost by using such mixtures, more properly described as creosote solutions of tar, more than balances the increased difficulty of impregnation. In further defence of so called "paving oils" or creosote-tar mixtures it has been maintained that the limits of density of straight distillate oils, as set forth in some specifications, are commercially impracticable. There has been considerable controversy on this subject, with a corresponding variety of practice among preserving plant operators. A large number of cities of the United States, with wide experience in the use of treated wood-block paving, now permit the use of creosote-tar mixtures, containing 30 per cent to 40 per cent of refined coke-oven tar, low in free carbon content, or an equal proportion of water-gas tar. On the other hand the conservative practice of specifying a tar-free oil for paving block treatment is still followed by many municipalities. It may be noted in this connection that water-gas tar creosote is rather lower in toxic value than coal-tar creosote and for his reason its use has been prohibited by some specifications for timber treatment. However there is need for more conclusive information on the subject of creosote-tar mixtures, and their relative value as preservatives.

It has been claimed, and recent experimental work by the Forest Products Laboratory of the United States Forest Service has shown, that the lighter fractions of creosote oil have much higher toxicity than the heavier constituents. The following extract



By permission of Canadian Wood Preserving Co., Winnipeg.

Construction of Treated Wood-block flooring in foundry.

Loading Platform of Creosoted Wood-blocks.

By permission of Dominion Tar and Chemical Co.

from a table showing relative toxicities of various wood preservatives, published in a report of an experimental investigation at Madison,[1] illustrates the comparative toxic value of the various fractions indicated:—

LIST OF PRESERVATIVES TESTED SHOWING ESSENTIAL PROPERTIES AND KILLING POINT.

—	Specific gravity at 60°C.	Per cent distills below.							Killing Point. (per cent.)	
		C.180°	C.215°	C.245°	C.275°	C.305°	C.320°	C.360°	Fomes annosus	Fomes pinicola
Water-gas-tar creosote, No. 1101	1·058	About 7·0	About 10·0	......	16·3	About 22·0	About 27·0	56·4	40	40
" " No. 2233	1·042	3·0	6·7	21·2	35·3	48·5	53·7	77·6	between 3 and 4	....
" " No. 2235	0·995	3·3	12·8	37·7	61·7	75·3	80·3	......	Around. 0·45	......
Coal-Tar creosote No. 1074	1·048	4·8	17·8	44·4	54·1	67·2	74·1	......	0·55	0·225
" " Fraction 1, No. 1094	0·934	35·1	78·3	......	......	......	......	......	0·30	0·225
" " " 2 " 1106	1·003	About 2 to 3	30·0	About 80·0	About 92·0	......	......	......	0·225	0·150
" " " 3 " 1107	1·045	......	0·9	16·2	49·2	77·7	85·0	......	0·325	0·125
" " " 4 " 1108	1·088	......	......	0·9	4·7	38·5	54·3	......	3·30	0·125
" " " 5 " 1109	1·150	......	......	......	......	4·1	10·1	49·7	33	7·800
Avenarius Carbolineum, No. 1843	(16·5°) 1·126	......	1·1	2·6	6·1	16·4	About 29·0	......	5·25	0·300

Typical creosote oil specifications are given below:—

Extract from the City of Toronto Specifications.

(1) Preservative. The preservative to be used shall be a product of coal-gas, water-gas or coke-oven tar, which shall be free from all adulteration, and contain no raw or unfiltered tars, petroleum compounds, or tar products obtained from processes other than those stated.

(2) The specific gravity shall be not less than one and ten-hundredths (1·10) nor more than one and fourteen-hundredths (1·14) at a temperature of thirty-eight (38) degrees Centigrade.

(3) Not more than three and one-half ($3\frac{1}{2}$) per cent shall be insoluble by continuous hot extraction with benzol and chloroform.

(4) On distillation, which shall be made exactly as described in Bulletin No. 65 of the American Railway Engineering and Maintenance of Way Association, the distillate, based on water-free oil, shall not exceed one-half ($\frac{1}{2}$) of one (1) per cent, at one hundred and fifty (150) degrees Centigrade, and shall not be less than thirty (30) per cent nor more than forty (40) per cent at three hundred and fifteen (315) degrees Centigrade.

(5) The oil shall contain not more than three (3) per cent of water.

Extract from Specifications of the City of Minneapolis.

The preservative to be used shall be a product of coal-gas, water-gas or coke-oven tar, which shall be free from all adulterations and contain no raw or unfiltered tars, petroleum compounds or tar products obtained from processes other than those stated.

(*a*) The specific gravity of the oil shall be at least 1·10 at a temperature of 38 degrees Centigrade.

(*b*) It shall be completely liquid at 35 degrees Centigrade and show no deposit on cooling to 22 degrees Centigrade.

(*c*) It shall not contain more than 3 per cent of matter insoluble by hot continuous extraction with benzol and chloroform.

[1] Humphrey and Fleming: "Toxicity of Various Wood Preservatives." Journal of Industrial and Engineering Chemistry, February, 1914.

(*d*) It shall be subjected to a distillation test as specified below, and shall conform to the following requirements: 100 grams of oil shall be placed in an 8-oz. retort, fitted with a thermometer, the bottom of the bulb of which shall be placed one-half inch above the oil and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer and the retort shall be covered to prevent too rapid radiation. The percentages are for dry oil and by weight. The average of a number of tests shall show a mean of these percentages, viz.:

Up to	150	degrees C.,	nothing must come off.
"	170	"	from 0 per cent to 0·5 per cent must come off.
"	210	"	from 2 per cent to 4 per cent must come off.
"	235	"	from 6 per cent to 16 per cent must come off.
"	355	"	from 40 per cent to 55 per cent must come off.

The distillation shall be gradual, and should be fully completed in forty minutes from the first drop. Thermometer readings to be corrected for emergent stem.

In the process of treatment of the blocks not more than 2 per cent of water will be permitted. The distillate from 170 degrees C. to 210 degrees C. will be approximately tar acids. Not more than 2 per cent of sawdust or other foreign matter will be permitted. (From 210 to 235 degrees C. will be naphthalene.)

Extract from United States Forest Service Specifications.

The creosote should be derived from the distillation of pure coal tar, free from any adulteration whatever or any mixture of undistilled tar. If it contain more than 3 per cent of water, a deduction in price corresponding to the per cent of water in excess of that amount will be made. It shall have a specific gravity at 60 degrees C. of not less than 1·04. When analyzed by the standard Forest Service method of analysis for coal-tar creosote, it shall have the following fractions, calculated on a moisture-free basis (when less than 3 per cent of water is present in the creosote, it shall be considered moisture free):—

(*a*) Up to 205 degrees C., not more than 5 per cent.
(*b*) Up to 235 degrees C., not more than 40 per cent nor less than 5 per cent.
(*c*) Up to 250 degrees C., not more than 50 per cent nor less than 15 per cent.
(*d*) Up to 295 degrees C., not more than 65 per cent nor less than 30 per cent.
(*e*) At 355 degrees C. the residue must be soft and not sticky.

On applying the sulphonation test to the fraction between 305 degrees C. and 320 degrees C. there shall be no oily residue insoluble in caustic alkalies.

The indices of refraction at 60 degrees C. shall be as follows for the following fractions:—

(*a*) At 250 degrees C., not less than 1·593 nor more than 1·602.
(*b*) At 290 degrees C., not less than 1·615 nor more than 1·622.
(*c*) At 300 degrees C., not less than 1·625 nor more than 1·632.

Extract from British Post Office Department Specifications for Creosote Treatment of Poles.

(*a*) To leave not less than 25 per cent nor more than 35 per cent residue when distilled up to a temperature of 316 degrees C.

(*b*) To contain not less than 15 per cent nor more than 25 per cent naphthalene.

(*c*) To contain not less than 5 per cent of phenol and other phenoloids.

(*d*) To be completely liquid at 38 degrees Centigrade.

(*e*) Not to contain more than 2 per cent of matter volatile at 100 degrees Centigrade.[1]

SIZE OF BLOCKS.

The general standard width of paving blocks is 3 inches or 4 inches. In America specifications usually permit considerable variation in the length of blocks, generally from 5 to 8 inches. This range of size permits economical utilization of timber-stock in sawing. English specifications apparently require greater uniformity in length.

American pavements are built of blocks ranging from 3 to 4 inches in thickness, and a maximum variation of one-sixteenth to one-eighth inch is permitted in the depth of the blocks used in any one pavement. As previously noted, European standards of depth of blocks are rather more liberal. A minimum of 4 inches is the general specification, and on heavily travelled thoroughfares 5-inch blocks are used. There is not unanimous agreement among paving authorities as to the economical standard of depth, but at present it is doubtful if the use of blocks of depth less than 3½ inches is justified, except on very lightly travelled streets. To what extent the total shearing resistance of a block is a measure of the durability of the pavement under service conditions is doubtful. This will depend in part on the character of the foundation and cushion. An experimental pavement has recently been laid at Tacoma, Wash., of 2-inch Douglas fir blocks, with a view to obtaining reliable service records of block pavement of this depth. In general, however, because of the clear straight structure of Douglas fir, 4 inches has been regarded as the safe minimum depth of such blocks, while even heavier blocks have been advocated by some authorities.

Conservative practice will require a minimum depth of from 3½ to 4 inches for blocks of all wood species, until reduction of depth is justified by ample and conclusive records of performance.

DESIGN AND CONSTRUCTION.

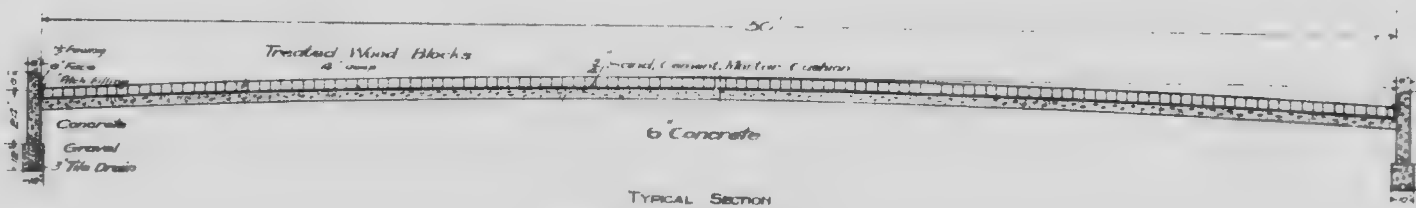
The importance of proper design and careful workmanship in construction, as factors contributing to the success of wood-block paving, can scarcely be overestimated. As noted before, a great proportion of the failures of wood paving in the United States and Canada in the past has been due to neglect of these factors, and the responsibility for the success of English pavements has been largely credited to the careful and thorough workmanship in construction.

A smooth, hard, relatively impervious wearing surface is the first requisite for durability, and unequal wear or subsidence of the blocks results in the development of "pot-holes" or areas of depression, which serve as collecting places for water and street refuse, and under such conditions deterioration is very rapid.

It may be noted at this point that all creosoted timber should be used as soon as possible after treatment. A certain amount of evaporation of the lighter oils is almost unavoidable, but this may be reduced by prompt use or careful storing, when that is necessary. When creosoted paving-blocks, with relatively large surface, are allowed to stand unprotected for any length of time before using, there may be an appreciable loss from evaporation of preservative. Moreover, if treated blocks which have been imperfectly dried are allowed to stand exposed to the sun, or loosely piled permitting free circulation of air, they will lose considerable water by evaporation, resulting in shrinkage. If blocks are closely laid in pavement in this condition expansion troubles are almost certain to follow. Care is therefore necessary to protect blocks during the interval between treatment and use, and if delay is unavoidable, they should be closely piled, covered and springled occasionally to prevent shrinking.

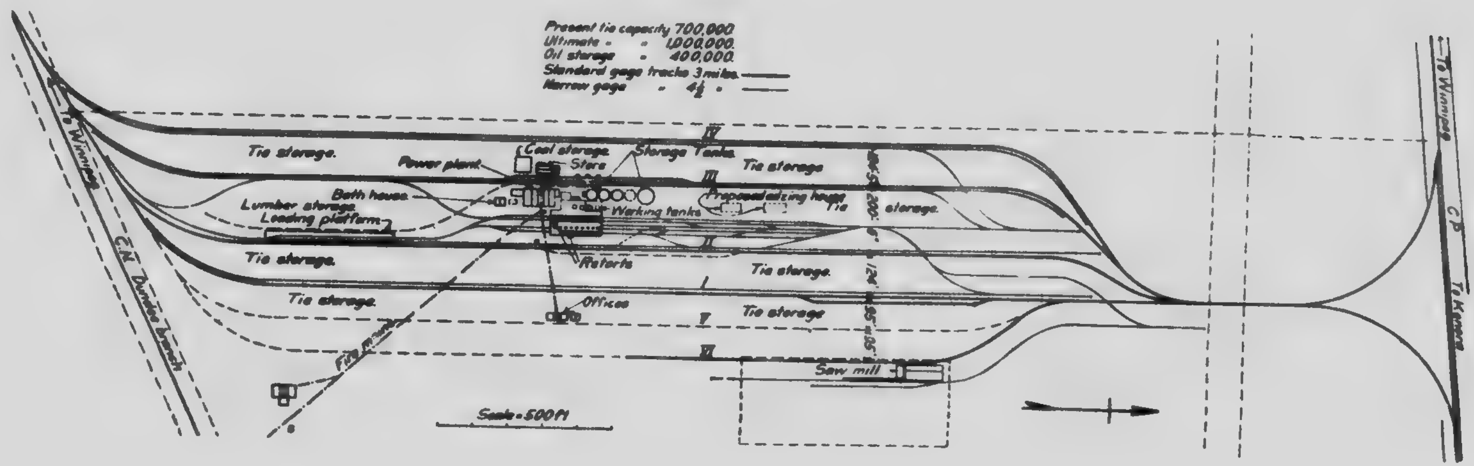
---

[1] S. R. Church: "Creosote Oil,—Specifications and Methods of Analysis." Proc. American Wood Preservers' Assoc., 1912.



TYPICAL SECTION

MODERN WOOD BLOCK PAVEMENT.



(BY PERMISSION OF DOMINION TAR AND CHEMICAL COMPANY)

GENERAL PLAN OF TRANSCONA PLANT OF DOMINION TAR AND CHEMICAL COMPANY

FOUNDATION.

The fundamental essential of a successful pavement is obviously a well laid foundation. This may be of 4, 5 or 6 inches depth, according to the width of street, condition of soil and character of traffic. Many engineers prefer a 6-inch foundation, realizing the possibility of damage from unequal subsidence over soft or recently disturbed ground. Concrete of 1:3:6 cement, sand and stone is the usual mixture. American operators agree that the English practice of finishing the foundation to an absolutely true smooth contour, thus removing the necessity of any cushioning material, increases the cost of construction to a prohibitive figure. The modern practice now in favour in the United States and Canada is to finish the concrete base to an approximately true contour, and use a cushion of 1:3 or 1:4 cement and sand mortar.

CUSHION.

This is spread on the cleaned and dampened surface of the foundation course, and struck off with a template to true contour. Such a cushion is three-quarters to 1 inch in thickness, according to the irregularity of the finished foundation surface.

The mortar cushion is mixed and spread dry, and sprinkled in advance of the laying of the blocks. After the blocks are placed, they are rolled to an even surface with a light steam roller. Care is necessary to provide that the placing and rolling of the blocks is completed before the mortar develops initial set. The necessity of longitudinal expansion joints has been amply demonstrated by past experience, and the universal practice is to provide at least three-quarters of an inch at each curb, using a course of longitudinal blocks as a facing for the courses of oblique blocks. This expansion allowance may be increased to 1¼ inches at each curb, or, if the street is laid with car tracks, additional expansion is provided at the rails. A 6-inch to 10-inch crown may be allowed acording to the width of the street, 8 inches being the usual provision for a 50-foot roadway. No transvers expansion joints are provided in best present practice, and the joints between courses should not be wider than one-eighth inch.

ANGLE OF COURSES.

The practice of laying the blocks at right angles to the curb line has been, and still is, general. However, it is now recognized that the joint wear from traffic is greatly reduced by laying the courses at angles varying from 45 to 67½ degrees to the curb line. It has been suggested that this method of laying also reduces the danger of buckling and heaving from expansion of the blocks. Since the tangential expansion of wood from moisture absorption is much greater than that in a longitudinal or radial direction, it is evident from the diagrammatic illustration of method of cutting from the log, that expansion in the pavement will be greatest in a direction parallel to the line of courses.

It has been claimed that the stresses developed under expansion are more evenly distributed where the courses are inclined to the street line. Just how far this contention is proved by results in practice is uncertain, but at least it has been conclusively shown that the joint wear is very materially reduced by inclining the courses to the street line, and apparently the angle of 67½ degrees has given best results.

FILLER.

Bituminous filler is now regarded as most satisfactory material for filling body-joints, and longitudinal expansion joints. This is applied hot and swept or squeegeed into joint cracks.

Such a filler may consist of pure coal-tar pitch or a mixture of pitch and asphalt. Care is necessary for the selection of a filling material of such consistency that it will not soften at the highest temperature to which it is to be exposed, and will not become brittle and unyielding at lowest temperature extreme. A usual specification

of coal-tar pitch for filler medium provides that it shall be the residue of distillation of coal tar only, shall be free from the lighter oils of coal tar, and shall have a melting point not lower than 142 degrees F. and not higher than 155 degrees F. Asphalt filler is a distillation product from asphaltic petroleum—distillation temperature generally specified not to exceed 700 degrees Fahrenheit. The filler is heated to a temperature of about 300 degrees F. and poured into joints, and worked in with a hand-broom or light hand-roller.

After filling is complete, a surface dressing of from one-half inch to 1 inch of clean sharp sand is spread on the pavement and left to be worn in by traffic.

Careful workmanship in all details is an essential, and particular care is necessary in placing blocks and pouring filler around manholes, gutters and catchbasins, to provide an impervious surface.

MAINTENANCE.

A feature of street paving which must be given some consideration, aside from the actual cost of maintenance and repairs, is the inconvenience and interruption to traffic resulting from repairs and renewals. In any type of brick or block pavement the substructure rarely requires attention, and the cost and frequency of repairs necessary are measured largely by the durability of the wearing surface.

In Europe wood-block pavements are regularly cleaned and flushed with water. Regular applications of sand surfacing are made to reduce slipperiness, and to renew the wearing surface.

A feature which has been emphasized in recent years is the necessity of careful workmanship in replacing pavement after service cuts. This is too frequently left to careless or inexperienced workmen. Some engineers have claimed that replacement of concrete pavement base, after cutting for excavation, should be reinforced to insure that there will be no subsidence over the area in which the earth has been disturbed.

The success of wood-block paving depends upon careful attention to such details, since the development of "pot-holes," or small areas of depression, results in very rapid deterioration of the blocks at such points. In cases where replacements are necessary, such work should be done under competent supervision, and precaution taken to have the renewed areas brought to true finished contour.

CANADIAN TIMBER-TREATING PLANTS.

The Canadian wood-preserving industry is represented at present by four producing companies: the Dominion Tar and Chemical Company of Sydney and Winnipeg, the Canada Creosoting Company, of Toronto, the Dominion Creosoting Company of Vancouver and Alex. Bruce & Company, of Fort Frances, Ontario.

Alex. Bruce & Company own and operate a plant located about four miles east of Fort Frances, on the main line of the Canadian Northern Railway, Port Arthur to Winnipeg. This plant is equipped for treatment by the Bruening-Marmetschke process, which employs as preservative medium a combined solution of zinc chloride and aluminum sulphate. The plant is provided with two cylinders, power-house and other auxiliary equipment for pressure treatment. Creosote has not been used at the plant and railway cross-ties have constituted the great part of timber treated.

The Dominion Tar and Chemical Company operates tar distillation plants at Sydney, N.S., and at Sault Ste. Marie, Ont., producing creosote oil. In connection with the distillation plant at Sydney the company operates a treating plant, equipped with one cylinder. This has been used chiefly for creosoting piling and railway cross-ties. The Transcona plant of this company is largely engaged in the treatment of railway ties at present, although the creosoting of wood-paving blocks is a growing part of the business.

(Courtesy of Canada Creosoting Company.)
Interior of Treating Shed, Canada Creosoting Company, Trenton, Ontario.

(Courtesy of Canada Creosoting Company.)
General view of Plant, Canada Creosoting Company, Trenton, Ontario.
Storage yards in background.

The plant is located about six miles east of Winnipeg, and has connection by Canadian Northern railway and Canadian Pacific railway with that city. There are ample storage yards in connection with the plant for the storing and seasoning of ties and other timber. The storage yards are served by four parallel narrow-gauge tracks, and a locomotive crane is used for handling material in the yards and at the treating plant.

The actual plant equipment includes four treating cylinders of 6 feet 6 inches diameter, three of which are 135 feet long, and a fourth of 84 feet length. Treatment of railway ties includes yard seasoning, or equivalent steaming and vacuum treatment of ties, followed by impregnation with creosote oil up to 3 gallons per tie.

Oil storage is provided by tanks of 20 feet diameter and 14 feet height. These are used as a source of direct supply for treating cylinders, and ample outside storage capacity for creosote is provided by five additional tanks. Power plant and machine shops complete the plant equipment.

By permission of Canada Creosoting Company

Southern pine and Norway pine paving-block stock in seasoning yard.

The *Canada Creosoting Company*, of Toronto, operates a plant at Trenton, Ont. This plant has recently been completed, and is equipped for pressure treatment of railway ties, paving blocks and other timber stock.

The plant is located on a property of 42 acres on the east bank of the Trent river. It has access to the Grand Trunk, Canadian Northern, and Canadian Pacific railways, and has facilities for water transportation. The plant equipment includes saw-mill, boiler plant of 200 horse-power capacity, and one treating cylinder of 133 feet length, 7 feet diameter. The cylinder is served with overhead oil tank, run-off tank, high pressure pumps and vacuum pump. Storage for creosote is provided by two outside tanks, capacity 150,000 gallons each.

The yards afford abundant capacity for storage and seasoning of timber stock. Transfer tracks serve the storage yards, and loading docks have been erected to facili-

tate loading of treated timber into standard cars. The plant has been designed with provision for the installation of a second treating cylinder of capacity equal to the one now operating.

The plant of the *Dominion Creosoting Company*, Vancouver, is situated on the north arm of the Fraser river. The company's property comprises about 22 acres, with a river frontage of 1,300 feet.

The company operates a saw-mill with a daily production of from 55,000 to 70,000 feet, board measure, per day of ten hours. The paving-block mill is equipped with two block-sawing machines, having a total capacity of 1,600 square yards of block pavement per day.

The creosoting plant proper includes two retorts of 7½ feet diameter and 100 feet long, designed for working pressure of 200 pounds per square inch. The equipment includes air and oil pumps, working and storage tanks for creosote oil, and steam plant of 100 horse-power capacity. The yard and plant buildings are served with transfer tracks between buildings and connecting with the loading pier on the river front. Canadian Pacific railway sidings provide additional shipping facilities.

COST-FIGURES IN CANADIAN PRACTICE.

Vancouver, Victoria, Calgary, Moosejaw, Winnipeg, Toronto, Hamilton, Ottawa, and Montreal are among the Canadian cities where wood-block paving has been adopted to some extent. Douglas fir has been used almost exclusively on the Pacific coast for paving-block manufacture. Hard (Southern or yellow) pine blocks have been imported by some of the Eastern cities, and Norway pine, tamarack and hemlock blocks are also in use. Birch and maple are regarded as valuable woods for such service by some authorities, although these species have not yet been adopted to any extent in Canada.

Initial and ultimate cost, durability, availability of supply and adaptability to conditions of traffic are factors upon which the choice of a pavement surface depends. The factor of availability of supply will influence Canadian practice, because of high transportation costs. In the East the supply of timber for paving-block manufacture will be drawn from Norway pine, tamarack, birch, hemlock, and maple. At the present time imported yellow pine blocks compare favourably in price with native wood blocks, but this is an anomaly due to present market conditions, and can hardly be expected to continue. The coast cities have hitherto used Douglas fir blocks almost exclusively. It is possible that such other species as tamarack or hemlock may replace fir for this purpose. At present there is a considerable diversity of opinion as to the suitability of Douglas fir for paving-block manufacture. Difficulties of treatment have hitherto been responsible for the development of some prejudice against this species, although it is claimed that this trouble has been overcome by recent improvements on methods of seasoning and impregnation.

The initial cost of wood-block paving is rather higher than for other types of pavement. Compared with asphalt surface on an equal foundation its first cost is considerably greater. The cost of wood-block pavement will vary considerably according to design, and more particularly in proportion to the cost of timber stock, cost of treatment and labour for construction. This variation ranges from $2.50 to $3.90 per square yard.

A cost-figure is reported from Minneapolis of $2.50 per square yard, representing an average of several years' construction. The cost of a 3-inch treated-block pavement in Moosejaw is reported as $2.84 exclusive of excavation. Vancouver reports as low a cost as $2.10 per square yard, exclusive of excavation and foundation. In this case the cost per yard of treated blocks was $1.35, half of which represents the actual cost of treatment. The timber stock was Douglas fir and a twelve-pound impregnation was required.

These figures can hardly be assumed as representative of costs in the East. Probably a fair cost-figure in Eastern Canada would be from $3.25 to $3.85 per square yard for a 4-inch pavement on a 6-inch foundation. This cost is slightly higher than that of brick pavement, and approximately the same as that of asphalt block.

It is claimed by some of the most extensive and successful users of treated wood-block pavements that when properly constructed, the relatively high durability of such pavement liberally discounts the greater initial cost, and reduces ultimate cost to a figure which compares very favourably with other types of road surface. Remarkably low maintenance costs are claimed for treated-block pavements, some of which have been in use for ten to fifteen years. It may be said that there are no cases of American wood-block pavements laid according to best recognized practice, which have been in service for a sufficient length of time to yield conclusive information as to the ultimate life of such pavements. However, the performance records to date of well constructed wood-block pavements, under a wide variety of service conditions, are such as to commend them to the careful and impartial consideration of all highway engineers.

BIBLIOGRAPHY.

GENERAL.

W. F. Goltra: "History of Wood Preservation." (Proc. American Wood Preservers' Association, 1913.)

D. I. Okes: "Wood Block Pavement from Construction Standpoint." (Proc. A.W.P.A., 1912.)

R. S. Manley: "The Construction of Creosoted Wood-block Pavements." (Proc. A.W.P.A., 1914.)

C. L. Hill: "Wood Paving in the United States." (U.S. Dept. of Agriculture, Forest Service, Cir. 141.)

Carlile P. Winslow: "Commercial Creosotes." (U.S. Dept. of Agriculture, Forest Service, Cir. 206.)

Arthur L. Dean: "The Estimation of Moisture in Creosoted Wood." (U.S. Dept. of Agriculture, Forest Service, Cir. 134.)

F. P. Spalding: "A Text Book on Roads and Pavements."

Ira Osborn Baker: "Roads and Pavements."

Geo. W. Tillson: "Street Pavements and Paving Materials."

CREOSOTE OILS.

Hermann von Schrenk: "Creosote Specifications and Analysis." (Proc. A.W.P.A., 1912.)

S. R. Church: "Creosote Oil—Specifications and Methods of Analysis." (Proc. A.W.P.A., 1912.)

David Allerton: "Creosotes and Creosoting Oils." (Proc. A.W.P.A., 1912.)

Carlile P. Winslow: "Commercial Creosotes." (U.S. Dept. of Agriculture, Forest Service, Cir. 206.)

IMPREGNATION.

Clyde H. Teesdale: "The effect of varying the preliminary air pressure in treating ties upon the absorption and penetration of creosote." (Proc. A.W.P.A., 1914.)

F. M. Bond: "Some tests to determine the effect upon absorption and penetration of mixing tar with creosote." (Proc. A.W.P.A., 1913.)

Howard F. Weiss: "A Comparison of Zinc Chloride with Coal-tar Creosote for Preserving Cross-ties." (Proc. A.W.P.A., 1913.)

David Allerton: "The preliminary treatment of timber to insure a more even and satisfactory impregnation with creosote." (Proc. A.W.P.A., 1913.)

R. H. White: "Results obtained by piling creosoted wood blocks closely in cages and the saving effected thereby." (Proc. A.W.P.A., 1914.)

PUBLICATIONS ISSUED BY THE FORESTRY BRANCH.

Annual Reports—Director of Forestry—1904 and following years.
Bulletin 1. Tree Planting on the Prairies.
" 2. Planting and Care of a Forest of Evergreens.
" 3. Dominion Forest Reserves.
" 4. Forest Products of Canada (up to 1908).
" 5. Forest Conditions in Crowsnest Valley, Alberta. (Out of print.)
" 6. Riding Mountain Forest Reserve.
" 7. Forest Fires in Canada, 1908. (Out of print.)
" 8. Forest Products of Canada, 1908.
" 9. Forest Fires in Canada, 1909. (Out of print.)
" 10. The Farmer's Plantation.
" 11. Forest Products of Canada, 1909: Lumber, Square Timber, Lath and Shingles.
" 12. Forest Products of Canada, 1909: Pulpwood.
" 13. Forest Products of Canada, 1909: Poles. (Out of print.)
" 14. Forest Products of Canada, 1909: Cross-ties Purchased.
" 15. Forest Products of Canada, 1909. (Bulletins 11, 12, 13, 14, 19 and 20.)
" 16. Forest Fires and Railways.
" 17. Timber Conditions on the Proposed Route of the Hudson Bay Railway.
" 18. The Rocky Mountains Forest Reserve.
" 19. Forest Products of Canada, 1909: Tight and Slack Cooperage; Boxes and Box Shooks.
" 20. Forest Produits of Canada, 1909: Tanbark and Tanning Extracts.
" 21. Forest Products of Canada, 1910: Poles.
" 22. Forest Products of Canada, 1910: Cross.ties.
" 23. Forest Products of Canada, 1910: Timber Used in Mining Operations.
" 24. Wood-using Industries of Canada, 1910: Agricultural Implements and Vehicles, Furniture and Cars and Veneer.
" 25. Forest Products of Canada, 1910: Lumber, Square Timber, Lath and Shingles. (Out of print.)
" 26. Forest Products of Canada, 1910: Pulpwood. (Out of print.)
" 27. Forest Products of Canada, 1910; Cooperage.
" 28. Forest Products of Canada, 1910. (Bulletins 21, 22, 23, 24, 25, 26 and 27.)
" 29. Timber Conditions in the Lesser Slave Lake Region.
" 30. Forest Products of Canada, 1911: Pulpwood.
" 31. Forest Products of Canada, 1911: Tight and Slack Cooperage.
" 32. The Turtle Mountain Forest Reserve.
" 33. Forest Conditions in the Rocky Mountains Forest Reserve.
" 34. Forest Products of Canada, 1911: Lumber, Square Timber, Lath and Shingles.
" 35. Forest Products of Canada, 1911: Poles and Cross-ties.
" 36. Wood-using Industries of Ontario.
" 37. Forest Products of Canada, 1911.
" 38. Forest Products of Canada, 1912: Pulpwood.
" 39. Forest Products of Canada, 1912: Poles and Ties.
" 40. Forest Products of Canada, 1912: Lumber, Square Timber, Lath and Shingles.
" 41. Timber Conditions in the Little Smoky River Valley (Alta.) and Adjacent Territory.
" 42. Co-operative Forest Fire Protection.
" 43. Forest Products of Canada, 1912. (Being Bulletins 38, 39 and 40.)
" 44. Wood-using Industries of the Maritime Provinces.
" 45. Timber and Soil Conditions in Southeastern Manitoba.
" 46. Forest Products of Canada, 1913: Pulpwood Consumption.
" 47. Forest Products of Canada, 1913: Poles and Cross-ties.
" 48. Forest Products of Canada, 1913: Lumber, Lath and Shingles.
" 49. Treated Wood-block Paving.
Circular 5. Planning a Tree Plantation for a Prairie Homestead.
" 6. Preservative Treatment of Fence-posts.
" 7. Manitoba a Forest Province.
" 8. The Forest Products Laboratories.
" 9. Chemical Methods for Utilizing Wood Wastes.
" 10. The Care of the Woodlot.